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AIRBORNE FOREST FIRE RESEARCH

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Section 1

SUMMARY

This study is a review of research relating to airborne fire fighting systems. Its purpose is to provide NASA/Langley Research Center with current information on the use of aircraft in forest fire operations, and to identify research requirements for future operations. The study includes a literature survey, interview of forest fire service personnel, analysis and synthesis of data from research reports and independent conclusions, and recommendations for future NASA-LRC programs.

Section 2

INTRODUCTION

The use of aircraft in the detection and suppression of forest fires dates back to a time prior to the Wright Brothers development of aircraft. The earliest recorded use was in the 1870's when hot air balloons were used in order to gain the advantage in altitude for observing forest fire operations. Since those early beginnings the development of aircraft use in forest fire operations has paralleled the development of the aircraft itself. Prior to World War II, the major use of aircraft was for detection and observation. As early as 1944, however, experiments were being conducted by the Ottawa Department of Lands and Forests in the use of a Stinson seaplane as an air tanker. This aircraft was modified by constructing water compartments in the pontoons which could be opened over the fires. In subsequent years, various techniques for water bombing have been evaluated. One technique is to drop water filled containers which burst when they hit the ground. Another is to drop containers which are exposed at various velocities and heights above the ground for a free release of water.

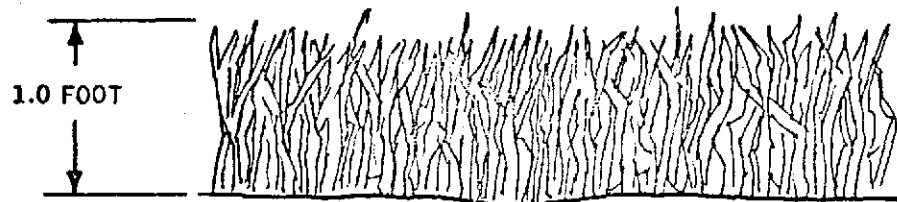
The first operational use of air tankers in the United States occurred in 1956. The Southern California Fire Control Agency using modified military surplus aircraft dropped more than 200,000 gallons of water and retardant solutions on a variety of fires. The success of this operation provided the impetus for continued use and by 1960 the air tanker was an accepted fire suppression tool.

Considerable research has gone into the development of retardant mixtures for fire control. Some of these early mixtures were detrimental to the forest and wild life after the fire suppression and have since been replaced by materials more acceptable to the post fire environment. Approved fire suppression chemicals are now available from industrial organizations. Research is continuing into the most effective chemical combinations as well as the water-retardant mixture for various fire conditions.

Thickening agents or jells have also been produced in order to reduce evaporation percentage of water and retardants released from the air tankers. In general, this provides for a greater percentage of released retardant reaching the ground. The particular mixture of water-retardant-jell to be used against a given fire depends primarily on the representative type of fuel as shown in Figure 1.

The use of aircraft in forest fire operations falls generally into three categories: observation, support and suppression. Many sizes and types of aircraft are in use in forest fire operations. Surprisingly, some of the older aircraft, such as B-17 and B-24 are still flying air tanker missions. Ground personnel charged with assigning aircraft to fire sectors indicated that these aircraft are used in the most difficult terrains and are being replaced only by rotary wing aircraft.

Fire fighting equipment and techniques vary according to the geography and specific local conditions. The overall use of aircraft, however, appears to be universal among developed nations and the exchange of information and aid between nations is providing additional benefits.



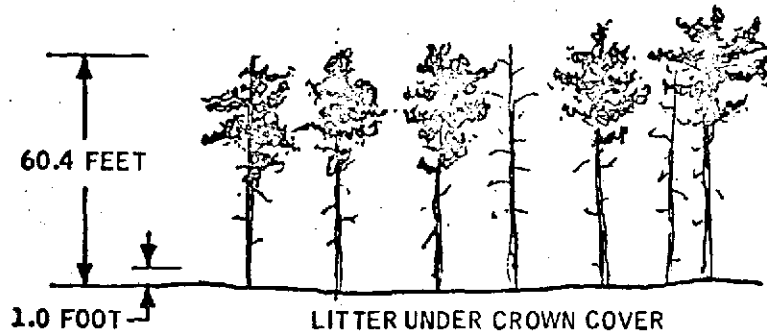
GRASS STAND



CHAPARRAL FIELD



DOUGLAS FIR CROWNS



LITTER UNDER CROWN COVER

Figure 1
Representative Fuel Types

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Section 3

THE FIRE PROBLEM

Most of us have seen the posters of Smokey the Bear (Figure 2) pointing to a sign which states that "9 out of 10 forest fires are caused by people." It is less well known, however, that the United States averages more than 100,000 fires per year on protected lands. Protected land includes those areas owned by federal or state government and large commercial tracts. Most of these fires are small and a large percentage of them are self-extinguished. A very small percentage account for the majority of the acres burned. Figure 3, fires and acres burned during 1963 - 1972, shows the dramatic effect of a very few fires which were not contained in their early stages and became uncontrollable. Figure 4 is a breakdown by year for fires of over 300 acres.

There are no statistics available as to the value of forest lands destroyed by fire and there is no general agreement as to forest values. The National Fire Council, in a 1967 report to Congress, used numbers which average \$50.00 per acre. Forest service personnel, however, feel that they can support numbers ranging from a high of \$2,000 per acre for prime forest land to a minimum value of approximately \$200.00 per acre. An estimate of loss incurred during 1969 (Figure 4) is that timber belonging to the Department of Agriculture and valued at 750 million dollars was destroyed.

A summary of data available from the United States, the USSR and Canada indicates that the United States has a far greater number of fires per given area than does the USSR or Canada. Table 1 is a comparison of fires per area of responsibility in the three nations. These data must be tempered by several considerations:

- (1) In the United States 9 out of 10 fires are attributed to human cause. This is apparently a much higher rate than is experienced in either the Soviet Union or Canada.

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Figure 2
Public Awareness

UNITED STATES
FIRES AND ACRES BURNED ON PROTECTED LANDS
C.Y. 1963-1972 AVERAGES

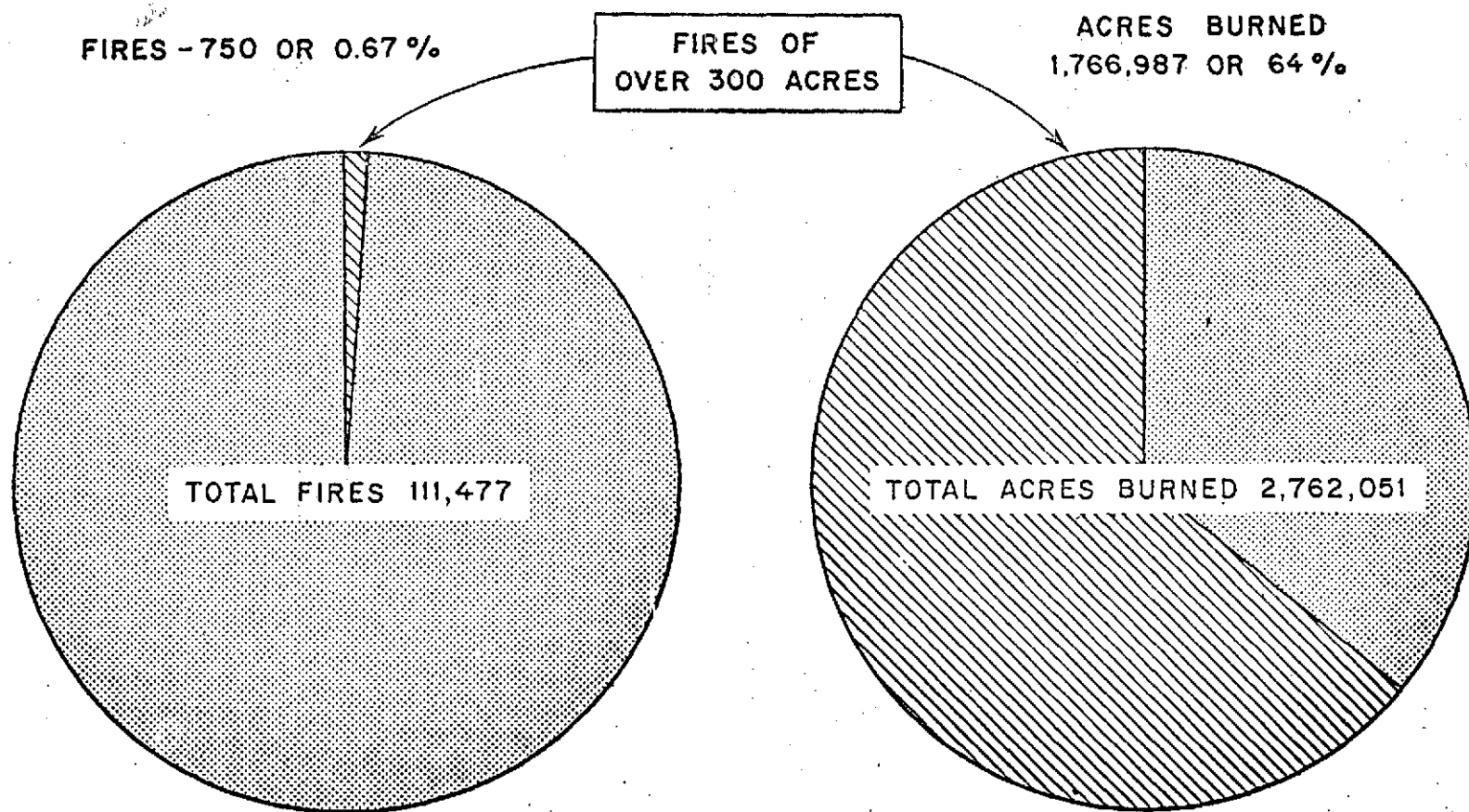


Figure 3
Fires and Acres Burned

UNITED STATES
CLASS E, F, G FIRES AND ACRES BURNED ON PROTECTED LANDS
C.Y. 1963 - 1972

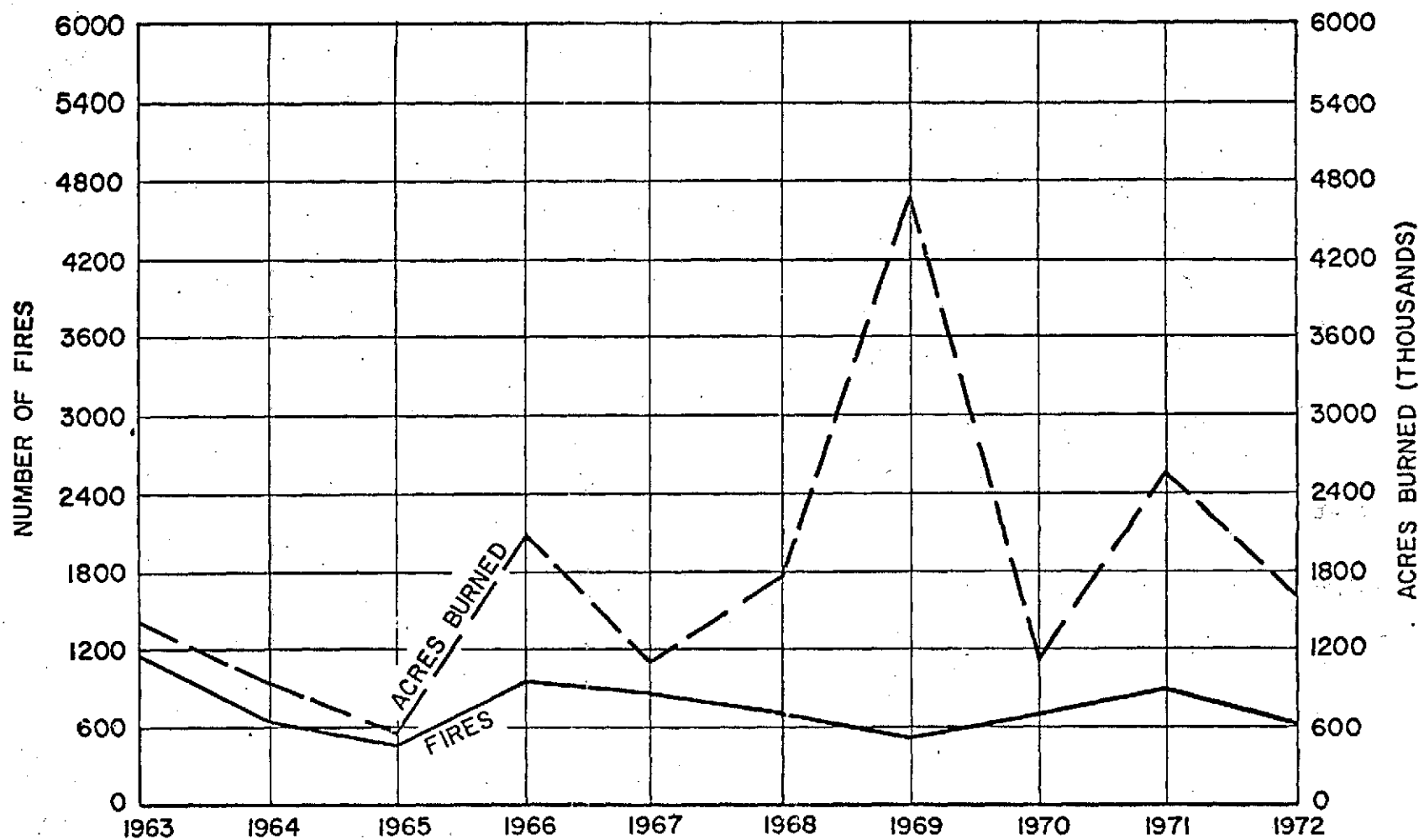


Figure 4
Fires of More than 300 Acres

- (2) It is believed that the percentage of reported fires versus number of fires is much higher in the United States than in the Soviet Union or in Canada.
- (3) The Soviet Union has a strong policy on the method of slash disposal at time of logging. Prescribed fire is not used but rather the slash is chipped and spread. This policy reduces the risk of escaped fires.
- (4) The Canadian experience is fewer fires but with a greater average burn area. This is primarily due to an inability to reach remote areas with equipment in the early stages of a fire.

It is interesting to note the differences in forest fire operations attributable to the differences in political system. In the Soviet Union, fire personnel are employed on a year around basis. Smoke jumpers and pilots continue training exercises and provide services such as teaching, or lecturing during the off season. They are career personnel and reportedly retire in less than 20 years. Both Canada and the United States use a combination of career personnel, and equipment and personnel leased for the fire season. Forest service personnel in all 3 countries indicated a desire for a high degree of centralized control. In the Soviet Union, aircraft and crews are controlled by local fire protection officials. There are, however, plans for a greater centralization. Canada has a system of centralized control with the various provinces working closely together and the crews and equipment following the fire season. In the United States, the recently developed inter-agency fire center located in Boise, Idaho coordinates fire fighting activities and provides for efficient use of aircraft and personnel. The method of attack on forest fires varies considerably between the United States, Canada and the Soviet Union. In the United States there is generally greater access by roads and containment crews can generally be delivered to the fire site by road in a reasonable time period. In Canada, there is less road accessibility, but a greater supply of water is available from the countless lakes. This accounts for the Canadian interest in seaplane operation and in the greater use of water without retardant. In the Soviet Union,

there is comparatively little road accessibility resulting in greater use of helicopters for delivery of personnel and equipment. The Soviet Union has just begun to use air tankers as a suppression tool.

The area of the United States is in excess of 2 billion acres. Over half of this is in forest and grass lands. The remaining area is comprised of 500 million acres of cities, highways, water areas and some 500 million acres which lie outside city levels in farm lands, small wooded lots, etc. Primary protection responsibility for forest and grass lands is divided among agencies of federal and state governments. The Department of Agriculture provides protection for over 200 million acres, the Department of Interior for over 400 million acres, and the States and local entities for more than 400 million acres of State and privately owned lands. It is estimated that some 420 million acres, primarily rural farm lands, are without organized protection.

TABLE 1 - FIRES VS AREA

	ACRES OF RESPONSIBILITY	AVERAGE NUMBER OF FIRES/YEAR	AVERAGE TOTAL BURN AREA ACRES/YEAR
USA - USDA	200 Million	20,000	.9 Million
USSR KARLLIAN	173 Million	750	NA *
USSR IRKUTSK	130 Million	1250	NA *
CANADA	> 3 Billion	6000	2.0 Million

* NA - NOT AVAILABLE

Section 4

AIRCRAFT OPERATIONS

In the United States there are approximately 145 fixed wing aircraft and a similar number of helicopters under lease to the Government for fighting fires during the fire season. Included among fixed wing aircraft in current use are: Boeing B-17's, Consolidated B-24's, Grumman F-7F's, North American B-25's, Douglas B-26's and Grumman TBF's. These aircraft have been modified for fire fighting by the installation of water tanks in the bomb bays. Typically, the B-17 carries 2,000 gallons and the B-24 approximately 2,400 gallons of water retardant mixture. The B-24 payload is carried in eight tanks which can be activated individually, in sequence, or all at once. Other modifications to the B-24 include replacement of the original engines with more powerful engines and improvements to cockpit visibility.

Additional aircraft being modified and evaluated for service as air tankers are the Lockheed P2V, the Grumman S2F, and Fairchild C-119, and the Douglas DC-6 and DC-7.

In many instances helicopters are being used to replace and supplement fixed wing aircraft as the older aircraft are being phased out. Although the helicopter has less load carrying capability, the number of targets available is significantly higher. Even though helicopters are being used more frequently, there are significant problems related to their use. Notable among these are the lack of available qualified pilots, and the interaction of the rotor downwash with the fire.

An observer of aircraft operations and the suppression of forest fires may be impressed by the similarity of this operation to the use of aircraft in support of ground troops in war time. A fire boss is responsible for calling in aircraft assistance when he deems it necessary. He is responsible to high authority for an efficient and economical operation. Unnecessary use of aircraft may deprive another fire boss of the use of air support where it is more urgently needed. Communications between ground operations and aircraft is a problem area in which the goal of complete satisfaction may never be reached; however, both the electronic aspects and the human factors aspects of ground to air communication are constantly being improved.

It is difficult to identify specific values of aircraft use in forest fire operations due to a lack of quantitative results. Fire fighting is a team effort and the success or failure of the overall operation is heavily dependent upon conditions, such as the weather, which are beyond human control. However, the effectiveness of the air tanker can be determined when it is used in an operation generally called "direct attack". Direct attack describes two techniques for suppressing small fires. A small fire may be a "jump fire" from a larger fire, or may be totally independent of any other conflagration. In the first technique, used when a single drop will totally encompass the fire parameter, the procedure is to make a single drop from one direction, and then return and make a second drop from another direction.

On the other hand if the pilot judges that a single retardant drop will not encompass the fire perimeter, or, if he judges that the fire intensity will not respond to a single drop, he will use the second technique and attempt to make a suppression drop on the fuel immediately in advance of the fire. In this case his approach options are fewer since he must cover

the entire frontal area of the fire. The pilot is generally given the freedom to choose his own approach and method of attack. The consensus of the pilots interviewed indicates that they make their evaluation of the size and condition of the fire based on past experience. In both types of direct attack experienced pilots have a high percentage of success as evidenced by the number of fires that are contained.

It must be recognized, however, that some of these fires would have gone out by themselves. It must also be recognized that the purpose of the air tanker is to contain the fire until a ground crew can arrive at the scene and perform a mop-up operation. Therefore even the quantitative results of direct attack must be viewed from the position of the fire boss who must conduct an efficient operation.

The other general technique of water bombing is identified as "line building". This technique is employed against fires of larger area or higher intensity and the attempt is to control the fire rather than to immediately snuff it. It has been particularly successful against grass fires. In this operation an air tanker such as the B-24 can sequence his release mechanisms and deploy a line of retardant 300 meters long by 20 meters wide.

The effect of line building against fires of greater ground cover is much more difficult to evaluate and is the subject of much disagreement. The economics of the use of air tankers is based primarily on its unquestioned value in direct attack on smaller fires. This study therefore has concentrated on the direct attack operation in an attempt to identify and understand the operation as a potential research area which could bear useful results.

Section 5

RESEARCH

Table 2 is a listing of current research sponsored by the United States Department of Agriculture Forest Service Division. This organization is the focal point for all forest fire research conducted by the federal Government. The Forest Service has three research centers located in Missoula, Montana; Riverside, California; and Macon, Georgia, in addition to two Equipment Development Centers located at San Dimas, California, and Missoula, Montana. Aircraft operations currently being studied concentrate on tanking and gating systems for control of drops.

TABLE 2 - AIRCRAFT RESEARCH PROJECTS (USDA)

CY 73 - CY 74	Systems Evaluation of Aerial Dispensing	Contract
	Helicopter Night Operations	In-House
	Modular Fire Fighting Platform	Contract
	Tank Weight and Balance	In-House
CY 74 - CY 75	Tank Weight and Balance	In-House
	Gating Systems	Contract

In addition to this work various state organizations are also supporting research activities into the various facets of fire fighting operations. Among the bibliography at the end of this report are the research reports available from the Canadian Government.

A large number of research studies have investigated drop patterns. These studies have varied drop height, drop speed, drop altitude and the quantity of the fluid. However, the drops are made generally at an airfield where recovery of the dropped material is possible. Extrapolation of this information to a drop on an actual fire, where updrafts are unknown, is highly questionable. Interviews with pilots indicate that they base their results to any specific research. Little data are available on the quantities and characteristics of material required to suppress a fire from the air. There's also little agreement on the characteristics that determine that value. Some sprinkler studies indicate that the primary effect of delivery from above a fire is the cooling of the adjacent fuel and the air above the flame. The sprinkler, however, provides a cooling flux whereas in aerial delivery it must be considered a cooling impulse. If this cooling impulse is the significant value of fire suppression in direct aerial attack then the addition of suppressants (for direct attack) is subject to question. The retardants and particularly the jell materials may reduce the rate of energy absorption of the water and thereby minimize its effect on the fire.

The cost of retardants in large quantities is approximately \$.25 per gallon. Fire service personnel estimate that 20 million gallons of retardant mixtures, or about 4 million gallons of retardant, are dropped on fires each year.

The phenomena of fire and fuel is under continual research as is the mechanics of dropping water and retardants from aircraft. Research on the interaction between these two subjects, however, does not appear to be available.

Section 6

POTENTIAL RESEARCH AREAS

The values of forest lands and the cost of protecting these lands against forest fires would appear to justify a significant research budget. The research centers of USDA forest service are faced with a variety of technical problems and a limited facility. In particular their capability to conduct research on aircraft operations is minimal and would benefit from a close association with the NASA facilities and particularly with Langley Research Center.

There are some specific areas of research within the Langley capability which could benefit the forest service operation. The Langley research into pilot displays such as the studies conducted in the "heads up" system could benefit the fire bomber by providing greater accuracy for his drops. Some of the instrumentation developed at Langley Research Center for the space program may be adaptable to fire fighting operations to provide greater information concerning temperature and weather conditions in and around fire areas.

The difficulties being encountered with the downdraft from helicopter rotors in fire areas may benefit from Langley Research.

A particular Langley Research Center Facility developed for the Lunar Landing Program could be adapted to the simulation of fire fighting problems. The Lunar Lander Research Facility, currently being used for crash worthiness testing, is the only such facility in the country capable of providing controlled conditions for repeated drops of quantities of water from reasonable heights above the ground. A major technical problem as discussed earlier in this report is the interaction of a cooling impulse generated by an air drop with the energy release of a small fire. The capability of the Lunar Lander Facility to provide repeatability of drop conditions as well as facilities for observation and analysis of results make it suitable for forest fire research.

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